Direct Digital Control System Energy Projects

Direct digital control (DDC) of heating, ventilating, and air-conditioning (HVAC) equipment has become a popular building retrofit. However, converting a building to DDC will not always save energy. In fact, it is not uncommon for energy consumption to increase after installing DDC equipment. This TechData Sheet provides information to help determine if a DDC project qualifies as an energy project.

Identifying a Valid DDC Energy Project

Installing a DDC system should only be considered for an energy project when the existing HVAC system is operating 24 hours a day and only needs to operate 12 to 14 hours a day. If DDC cannot be justified from the savings of night shutdown, it rarely will be a cost effective energy project. Therefore, base your economic calculations on energy savings from fan and cooling equipment that can be shut off. Carefully consider the following when evaluating a candidate building.

Reasons that DDC may increase energy consumption in buildings are:

- Automated switch over between heating and cooling may happen more frequently than manual switch over.

- Outside air dampers are closed before the retrofit.

- Existing HVAC systems are shut off manually due to poor temperature control.

The following are valid reasons to install DDC. Note that only the third situation is by definition an energy project.

- During all new construction and major retrofits of facilities.

- When existing controls are not working and are beyond their useful life.

- When existing controls systems can be replaced by more efficient controls and the project can be based on energy savings.

- When you need to improve temperature control within a building.

Estimating Project Savings

The following items are potential savings that may be included in a DDC energy project:

- *Energy*: DDC has the potential to reduce HVAC energy consumption by programming the controls to optimize facility energy use. DDC allows the operator to fine tune building operations, but large energy savings beyond what can be done with a simple timeclock is not common.

- *Electrical Demand*: DDC systems can be programmed to limit peak electrical demand. Savings from electrical load shedding must be considered carefully and must be coordinated with building occupants. For example, it's easy to claim chiller or fan savings during peak conditions, but the demand savings may be canceled by occupant discomfort, increased fan power consumption, or reduced indoor air quality. There are valid reasons for demand limiting, but you should carefully consider the impact.

- *Maintenance*: DDC will reduce controls calibration time by 80 percent over pneumatic controls, assuming controls calibration is currently performed. DDC will also reduce time spent troubleshooting failed controls, allowing more time for preventive maintenance on the HVAC systems.

The best method to estimate mechanical system energy savings is to model the thermal performance of a building. The model requires calculating the building's overall "U" factor, and determining the internal building loads (lighting, people, and office equipment). Building modeling requires knowledge of heat load calculations. Several building energy modeling software programs are available (e.g., DOE II, Trane Trace, ASEAM). All of these programs are based on load calculations and material thermal factors, found in the ASHRAE Handbook "Fundamentals," 1993. Building heat load calculations may also be performed by hand.

If you are not going to model the building's thermal conditions, we recommend following the example below to estimate energy savings for a DDC project. Again, if a DDC system cannot be justified on simple start/stop savings, a project will rarely meet the Energy Program's payback criteria.

Example Project

• The building control system is an electronic control system that has not worked as designed for 5 years. Occupants complain of cold temperatures during the cooling season. The air handling unit (AHU) and direct expansion (DX) unit operate 24 hours a day, 365 days a year. Building hours of operation are Monday through Friday, from 7 amto 6 pm.

• The mechanical system consists of 1 variable air volume (VAV) AHU, 5 VAV boxes, 1 hot water (HW) system, and a DX unit.

• This sample project calculates simple payback only. A project submittal must include a complete life cycle cost (LCC) analysis. The Navy's LCC spreadsheet uses a 10-year life for DDC projects.

• Cooling is required above 60°F outside air temperature

• Estimated full load design safety factor is 120 percent

• Cooling season is 5 months per year

• HVAC system starts 1 hour before occupancy

• Mild night temperatures eliminate the need for fan operation during unoccupied hours. The existing control system has the fan running all night.

Determine motor energy consumption and fan savings:

a. Measure or determine motor amperage and calculate motor kilowatts (kW).

Measured Fan Motor Amperage:
AHU Supply Fan Full Load = 21 Amps

Determine Nameplate DX Amperage:
DX Condenser Unit Full Load = 61 Amps

Motor Voltage = 208

AHU kW = (V x A x 3[^1/2] /1000) x power factor
= (208 x 21 x 1.73 / 1000) x 0.9
= 6.8 [kW]

DX kW = V x A x 3[^1/2] /1000 x power factor
= (208 x 61 x 1.73 / 1000) x 0.9
= 19.8 [kW]

b. Calculate hours fan motors may be turned off annually.

Hours saved = (12 [hrs/day] x 5 [days/week] x 52 [weeks/year]) + (48 [hours/weekend] x 52 [weekends/year]) + (10 [holidays] x 12 [hours/holiday]) = 5,736 [hours]

c. Determine the energy savings in kilowatt-hours (kWh) from turning the fans off.

• Fan energy savings:

kWh/Yr = kW x hours off
= 6.8 [kW] x 5736 [hours]
= 39,004 [kWh]

$ Savings = kWh x electric rate = 39,004 x 0.1 [$/kWh]
= $3,900

Use the bin method to estimate reduced cooling loads:

a. Estimated current cooling season (typically 4 to 7 months)

Cooling Season = 21 weeks (5 months)

b. Estimate the percent of hours the cooling equipment may be shut off for the different BIN weather data periods (e.g., BIN weather data are usually divided into three periods, between midnight (00) and 08, 08 and 16, and 16 and 24 hours periods during the day).

If the equipment may be shut off between 1800 and 0600 daily and for 24 hours on the weekend:

Total hours for each 8-hour period over the 21-week cooling season:

= 8 [hours/day] x 7 [days/week] x 21 [weeks/cooling season]
= 1,176 hours

Hours cooling equipment may be turned off:

0000 - 0800 = (6 [hrs/day] x 5 [days/week] x 21 [weeks/cooling season]) + (16 [hours/weekend] x 21 [weekends/year]) + (3 [holidays] x 6 [hours/holiday])
= 984 [hours off]

% of total hours = 984/1176 = 83.7%

0800 - 1600 = (16 [hours/weekend] x 21 [weekends/year]) + (3 [holidays] x 8 [hours/holiday])
= 360 [hours off]

% of total hours = 360/1176 = 30.6%

1600 - 2400 = (6 [hrs/day] x 5 [days/week] x 21 [weeks/
cooling season]) + (16 [hours/weekend] x 21
[weekends/year]) + (3 [holidays] x 6 [hours/holiday])
= 984 [hours off]

% of total hours = 984/1176 = 83.7%

c. Chillers are often oversized and therefore have additional capacity at design conditions. Estimate the extra capacity of the chiller at the design outdoor temperature (this is the actual cooling safety factor). Use 20% extra capacity if not known.

Estimated Full Load Design Safety Factor = 20% (120% of design conditions)

d. Determine the outside air temperature at which the cooling equipment has to operate to cool the building (base cooling temperature) and the design outdoor temperature. The base cooling temperature is typically between 55 and 60°F. Design temperature is based on ASHRAE Fundamentals Design Weather Data.

Cooling is required above 60°F outside air temperature.
Design temperature is 100°F outside air temperature.

e. Using BIN weather data, determine the BIN hours the cooling equipment may be shut off for different percent loads. Use the following percent loads: 25, 50, 75, and 100%. To estimate these determine the hours for each temperature band (see Table 1).

Difference between cooling base temperature and design temperature:

= Design temperature - Base cooling temperature
= 100 - 60 = 40°F

f. Estimate cooling energy saved during unoccupied hours.

The DX unit draws 19.8 [kW]/1.2 [cooling safety factor] = 16.5 [kW] at design outdoor air temperatures. At 75% = 0.75 x 16.5 = 12.3 kW, 50% = 0.50 x 16.5 = 8.2 kW, and 25% = 0.25 x 16.5 = 4.1 kW.

The total cooling energy saved is:

% Load	Hours	kW	kWh
25	1,263	4.1	5,178
50	718	8.2	5,887
75	342	12.3	4,206
100	5	16.5	82
			15,353

$ Savings = kWh x electric rate
= 15,353 x 0.1 [$/kWh]
= $1535

Total Savings from Fan and DX Unit Shutdown:

$/Year = $3,900 + $1,535
= $5,435 Annual Savings

Costs:

$ 3,000 - AHU
775 x 5 VAV Boxes = $3,875
5,000 - Mechanical Room Controller
12,600 - Workstation Computer & Graphics Software
$24,475

Simple Payback = $24,475/$5,435 = 4.5 years

Table 1.

Range (%)	BIN Temp Range	0100 to 0800	% Hours Off	Hours Off	0900 to 1600	% Hours Hff	Hours Off	1700 to 2400	% Hours Off	Hours Off	Total Hours Off
25	60 to 69	752	83.7	629	98	30.6	30	722	83.7	604	1,263
50	70 to 79	296	83.7	248	588	30.6	180	346	83.7	290	718
75	80 to 89	128	83.7	107	473	30.6	145	108	83.7	90	342
100	90 to 99	0	83.7	0	17	30.6	5	0	83.7	0	5
		1,176		984	1,176		360	1,176		984	2,328

DDC Cost Estimating

There are three methods to estimate DDC system costs:

1. For retrofit projects, the cost may be based on a cost per point for major mechanical systems, (e.g., chilled water (CW) system, HW system, AHUs) plus a unit cost of converting terminal equipment to DDC, (e.g., VAV box, fan coil unit).

2. For new construction we recommend estimating the cost based on actual points and controllers.

3. Experience

Method 1

For the retrofit of building control systems, the general guidance in estimating the cost of DDC is between $200 to $500 for each input/output point. This cost estimating method is dependent on the total number of points in the project. Table 2 outlines these costs. When estimating the cost of terminal controllers (e.g. VAV box, fan coil unit) use $500 to $750 per piece of equipment for the controller, sensor, wiring, and programming. There are numerous issues that affect cost. Example equipment issues are whether conduit has to be run, whether actuators require replacement, and the number and type of workstations. Procurement issues include the level of competition for the project. The cost estimates are only rough. If you desire a better estimate, use Method 2 and tailor the costs to the actual installation.

Table 2. Estimating DDC Cost Per Point for Retrofit Projects

Total Points	Cost $/Point
50	500
100	400
300	350
500	300

Method 2

For new construction, use the cost of input/output points plus the cost of controllers. Table 3 includes sample DDC costs from "Means Mechanical Cost Data 1995." The sensor cost includes the cost of the sensor, cable, and 150 feet of conduit. Refer to the "Means" book for costs of all inputs and outputs.

A Successful DDC Program

A successful DDC program should have four components. The **first** is to optimize operations in all buildings with DDC. **Second**, identify all DDC projects that are cost effective based on an energy savings. **Third**, ensure all new construction is equipped with DDC. **Fourth**, identify DDC projects not justified by energy savings.

1. **Optimize Existing Building Operations:** Go out and learn building operations and optimize buildings that currently have DDC. We encourage activities, especially maintenance departments, to develop expertise with DDC systems. DDC when combined with knowledgeable operators can produce additional energy savings, not usually available from the typical construction process.

2. **Identify DDC Energy Projects**: You must survey your buildings to identify candidates for possible night shut down since it is the key component of a cost effective DDC energy project. During this survey, talk with occupants, building managers, and the people responsible for operating and maintaining HVAC systems. There are several reasons buildings are not shut off at night. Common reasons HVAC equipment runs at night are:

• Space temperature controls cannot recover from a night shut down.

• Relative humidity rises too high during a shutdown.

• Occupants use the building during unoccupied hours.

Table 3. Cost of Direct Digital Control Systems

Equipment	Total* (each)

Sensors (varies in cost - includes 150-ft conduit)
    Temperature (approximate)
    Pressure (approximate)
	
	$340
	$500

AHU or Mechanical Room Controllers
    16-point controller (e.g., AHU controller)
    32-point controller (e.g., CW/HW system controller) (Includes software programming, checkout, and 50-ft run in conduit)
	
	$3,000

Terminal Controller (e.g., VAV box controller) (includes sensor)	$775
Workstation Computer and Basic Software	$9,000
Graphics Software	$3,600

*Includes overhead and profit

Rarely do these reasons prove to be true if the controls and mechanical system work properly. Common justifications for operating a building 24 hours per day are:

• Equipment within the building requires special temperature and/or humidity control (although often a dedicated, standalone system can maintain proper conditions without operating the entire building's mechanical system).

• Comfort - a building operating at the same temperature all the time will be more comfortable to occupants than one that is shut down at night. Although the space temperature may reach setpoint, the walls and furniture continue to radiate the cooler (or higher) temperatures from the off period.

• Perceived indoor air quality - buildings shut off tend to become stuffy. This does not necessarily reduce indoor air quality, but occupants may be uncomfortable.

Consider all of the above factors when selecting buildings for DDC retrofit.

3. **Ensure New Construction Includes DDC:** Ensure current MILCON and large retrofit projects are installed with DDC. Follow the design guidance given in the DDC Technology Techdata Sheet, NFESC TDS-XXX.XX.

4. **Identify DDC "Non-Energy" Retrofit Projects**: Identify buildings with temperature controls that do not work. These control systems cannot perform their function and are good candidates for "non-energy" DDC retrofit projects.

Remember when retrofitting older systems, you must evaluate the other mechanical system components; actuators, dampers, valves, coils, pumps, etc. for proper operation. DDC can only improve control if the mechanical components are in good operating condition. This step is necessary for both energy and non-energy DDC projects.

If you have any questions about direct digital controls, call ESC20 at (805) 982-1465, DSN 551-1465.